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Permissible limit for mandibular expansion

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SUMMARY In recent years, mandibular expansion has been increasingly performed in conjunction with orthodontic treatment. Lateral tipping of the molars associated with mandibular expansion should, however, be considered, because excessive expansion may result in excessive buccal tooth inclination, which may disturb the occlusal relationship. This study was conducted to quantitatively clarify molar movement during mandibular expansion using the Schwarz appliance to determine the permissible limit of mandibular expansion as a clinical index for inclination movement. Inclinations in the masticatory surface of the first molar and intermolar width were measured before expansion (T1), after expansion (T2), and before edgewise treatment (T3). Lower plaster models from 29 subjects treated with expansion plates were used and compared with models from 11 control subjects with normal occlusion.

The average treatment change (T1–T2) in intermolar width was 5.42 mm (standard deviation 1.98), and the average angle of buccal tooth inclination was 10.16 degrees (standard deviation 3.83). No significant correlation was found between age prior to treatment and the treatment period when they were compared with the intermolar width increments and inclination angles. There was a significant positive correlation between retention duration and the amount of expansion. The regression coefficient of the angle of buccal tooth inclination during expansion to the increment of the intermolar width was approximately 0.2. This means that 1 mm of expansion is accompanied by 5 degrees of molar lateral tipping. This coefficient is clinically useful for estimating the permissible limit for mandibular expansion.

Introduction

Edward Angle opposed extractions as part of orthodontic treatment, and there was substantial controversy on this topic in the early twentieth century (Dewel, 1964, 1981). This controversy still continues today, and a universal solution has not yet been reached.

The heated extraction or non-extraction argument originated from the mandible not having any suture; rapid maxillary expansion increases the transverse dimension of the maxillary arch by separating the suture (Haas, 1961; Wertz, 1970; Bishara, 1987), but the mandibular expansion effects are localized to the alveolar bone and primarily induce tooth inclination (Haas, 1961). These effects are thought to be related to relapse.

Adequate occlusal contact relationships provide normal stomatognathic functions. The occlusal relationships are related to the mesio-distal and bucco-lingual tooth inclinations, in addition to the morphology of the masticatory surface of the molars. Mandibular expansion, which is not involved in this controversy, has been increasingly performed in orthodontic clinics in recent years (Hamula, 1993; Ogihara *et al.*, 1998). Before mandibular expansion is performed, however, uprighting posterior teeth during expansion must be considered. Mandibular expansion can result in excessive buccal tooth inclination, which may obstruct normal occlusal functions.

There are very few studies that have examined mandibular expansion effects (McNamara and Brudon, 1993; Housley *et al.*, 2003), in spite of its clinical importance. This study was conducted to quantitatively clarify molar movement during mandibular expansion, and then to determine a permissible limit as a clinical index for inclination movement.

Subjects and methods

Experimental group

The study group included 29 subjects, 10 males and 19 females, with an Angle Class I malocclusion without posterior crossbite, exhibiting some crowding in the lower dental arches [average arch length discrepancy: 5.24 mm (standard deviation: 1.40)] without restorations covering the cusp tips, who required mandibular expansion without extractions. All subjects were treated with a Schwarz appliance (Figure 1) to expand the molar and canine widths. Their ages ranged from 6 years 10 months to 11 years 7 months. The maxillary dental arches were also expanded using a Schwarz appliance in all patients in order to maintain the labio-lingual relationships of occlusal contact in the posterior teeth during expansion. After expansion, removable maintenance plates were used full-time to stabilize the expanded maxillary and mandibular dental arches while awaiting the eruption of the permanent teeth (4–6 months). Plaster models were made prior to expansion (T1), at completion of expansion (T2), and just before comprehensive treatment with an edgewise appliance (T3).

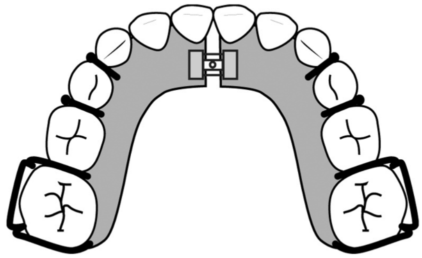

Figure 1 A diagram of the Schwarz appliance used in this study.

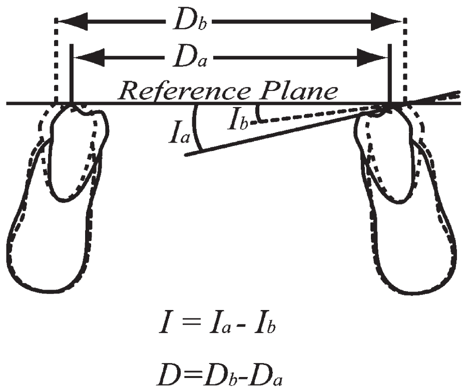

Figure 2 Measurements and calculations for the amount of expansion (D) and the angle of molar inclination (I). The solid line indicates pre-expansion and the dotted line post-expansion.

The reference plane, i.e. the lower occlusal plane including the midpoint of the tips of the right and left central incisors, as well as the mesio-buccal cusp tips of the right and left first molars, was defined. Defining a plane including the mesio-buccal, disto-buccal, and mesio-lingual cusp tips of the first molar as the masticatory surface, the angle between this plane and the reference plane was measured for each model at T1 and T2 (Figure 2). The difference between the angles at T1 and T2 (I) was defined as the degree of inclination associated with lateral expansion. In order to calculate the increments of intermolar width (D), the lengths between the right and left tips of the mesio-buccal cusps of the first molars on the models were measured at T1 and T2.

Control subjects

The control subjects included 11 children, four boys and seven girls, each exhibiting minimum crowding (less than 1 mm discrepancy) and an Angle Class I occlusion without restorations covering the cusp tips. The data were obtained from longitudinally taken lower plaster models at the Department of Orthodontics, School of Dentistry, Nihon University. The gender distribution was matched to the experimental group. Age matching was also performed to the experimental group at T1, T2 and T3 based on the mean age.

The reference plane and masticatory surface of the first molar was defined using the methods described above.

The three-dimensional (3D) measurements were obtained using a contact 3D measuring system (Tristation 400mcnc, Nikon Corp., Tokyo, Japan) (Figure 3). This high precision 3D measuring system has errors of less than 1/1000 mm in the x, y and z axes. One examiner (S.S.) measured all the models to eliminate inter-examiner errors. All the measurements were performed at least twice to reduce intra-examiner errors, and the mean values were used. When there was more than 1 mm difference in any axis of the x, y and z coordinates, the models were remeasured and the mean value of the three measurements was used.

Statistical analysis

Descriptive statistics were calculated for each measurement. The data were analysed using a statistical software package (SPSS 8.0 for Windows, SPSS Inc., Chicago, Illinois, USA). Treatment changes between T1, T2, and T3 were analysed with multiple comparisons (Scheffe test) on the basis of analysis of variance. Independent sample t-tests were performed to analyse variable differences between the control and treatment groups. Pearson's correlation coefficients were calculated for age at T1, treatment period (T1–T2), retention period (T2–T3), tooth inclination angle, and intermolar

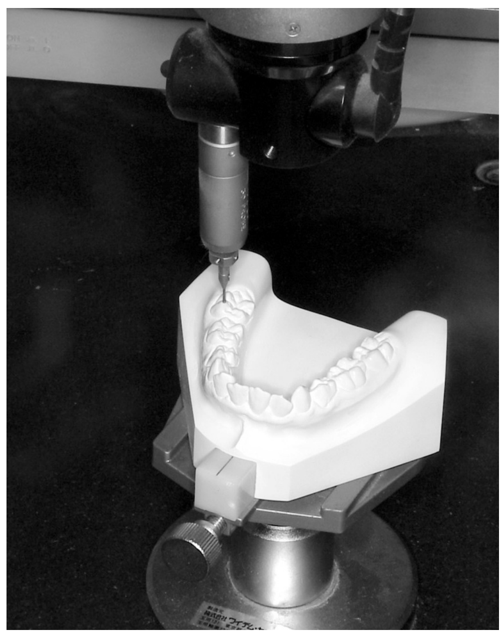

Figure 3 The contact three-dimensional measuring system used to measure the lower plaster models.

width increment. Linear regression analysis was then performed in order to obtain an index estimating the permissible limit for mandibular expansion.

Results

Tables 1 and 2 show the results derived from measurements for the treatment and control groups. Significant treatment changes were observed at T1–T2 and T1–T3 in the treatment group. In the control group, the only significant difference was at T1–T3 for molar inclination. Significant differences between the treatment and control groups were found for intermolar width at T2 and molar inclination at T1 and T2 (Table 3). The intermolar width at T2 in the treatment group was significantly greater than in the control group, the molar inclination at T1 in the treatment group was smaller than in the control group, and the molar inclination at T2 in the treatment group was greater than in the control group. Changes in intermolar width and molar inclination showed significant differences at T1–T2, T2–T3 and T1–T3. The T1–T2 and T1–T3 values in the treatment group were greater than in the control group, while T2–T3 values in the treatment group showed negative values and were smaller than in the control group.

Pearson's correlation coefficients among the variables are shown in Table 4. No significant correlation between age prior to treatment and treatment period were found compared with the expansion amount and the molar inclination changes for T1–T2. Significant positive correlations for T2–T3 were observed between the expansion amount and the retention period, as well as between the mean inclination of the right and left molars and the retention period. The amount of expansion and the retention duration revealed a significant positive correlation for T1–T3 (Table 4).

Table 5 shows the results of the linear regression analysis. A significant correlation was found between molar inclination and the amount of expansion. Regression coefficients of the angle of buccal tooth inclination [independent variables (degree)] to the increment of the intermolar width [dependent variables (mm)] were then calculated: 0.20 (P < 0.001) for estimates from T1 to T2, and 0.18 (P < 0.001) for estimates to T3.

Table 1 Descriptive statistics for the treatment group (n = 29).

	Pre-treatment (T1)		Post-treatment (T2)		After retention (T3)		T1–T2		T2–T3		T1–T3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	8.32	0.91	9.67	0.99	10.10	0.93	1.35	0.56	0.43	0.19	1.78	0.58
Intermolar width (mm)	44.28	2.64	49.70	2.79	48.40	2.66	5.42*	1.98	–1.30	1.76	4.12*	1.99
Molar inclination (degrees)												
Left	12.82	6.53	2.46	7.77	4.54	7.68	10.37*	4.75	–2.08	3.27	8.28*	4.91
Right	14.63	11.45	2.65	6.69	4.36	6.49	9.95*	5.17	–1.71	4.09	8.24*	5.44
Mean	13.73	7.17	2.55	6.44	4.45	6.23	10.16*	3.83	–1.90	3.15	8.26*	3.69

*Treatment change significant at $P < 0.05$.
SD, standard deviation.

Table 2 Descriptive statistics for the control group (n = 11).

	Pre-treatment (T1)		Post-treatment (T2)		After retention (T3)		T1–T2		T2–T3		T1–T3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	8.16	0.20	9.29	0.37	9.84	0.46	1.14	0.33	0.55	0.33	1.69	0.42
Intermolar width (mm)	45.55	1.82	46.09	2.13	46.73	1.99	0.55	0.41	0.64	0.39	1.18	0.39
Molar inclination (degrees)												
Left	8.32	3.62	7.00	2.83	4.14	2.35	1.32	2.47	2.86	1.73	4.18*	2.45
Right	8.00	3.07	6.73	2.61	3.91	2.44	1.27	2.10	2.82	2.67	4.09*	2.84
Mean	8.16	3.11	6.86	2.53	4.02	2.23	1.30	2.11	2.84	1.73	4.14*	1.94

*Change significant at $P < 0.05$.
SD, standard deviation.

Table 3 Significant differences between the treatment and control groups.

	Pre-treatment (T1)	Post-treatment (T2)	After retention (T3)	T1–T2	T2–T3	T1–T3
Age (years)	NS	NS	NS	NS	NS	NS
Intermolar width (mm)	NS	*	NS	*	*	*
Molar inclination (degrees)						
Left	*	*	NS	*	*	*
Right	*	*	NS	*	*	*
Mean	*	*	NS	*	*	*

Degrees of freedom = 38.
*Significant at $P < 0.05$.
NS, not significant.

Table 4 Pearson's correlation coefficients.

	T1–T2		T2–T3			T1–T3		
	Age pre-treatment	Treatment duration	Age pre-treatment	Treatment duration	Retention period	Age pre-treatment	Treatment duration	Retention period
Amount of expansion	–0.093	0.124	–0.103	–0.210	0.402*	–0.184	–0.062	0.374*
Left molar inclination	–0.176	0.073	0.128	0.059	0.268*	–0.085	0.110	0.145*
Right molar inclination	0.103	0.124	–0.036	–0.300	0.357*	0.071	–0.108	0.243*
Mean inclination	–0.040	0.129	0.043	–0.164	0.371*	–0.004	–0.006	0.276*

*$P < 0.05$.

Table 5 Linear regression analysis of molar inclination to the amount of expansion.

	Estimation for T2	Estimation for T3
Regression coefficient	0.20	0.18
Standard error	0.02	0.02
Correlation coefficient	–0.43	–0.50
R^2 value	0.19	0.25
t value	11.99	8.60
Significant	$P < 0.001$	$P < 0.001$
Degrees of freedom	28	28

Independent variable: the angle of buccal tooth inclination; dependent variable: the increment of intermolar width.

Discussion

In interpreting the results derived from this study, errors in measuring variables must be considered. The reference plane was defined by the occlusal plane on the dental models before and after expansion. It must be emphasized that the occlusal plane commonly changes during orthodontic treatment.

This study measured the changes of the masticatory surface of the first molar during expansion, although it is also possible to measure the tooth axis in order to obtain the tooth inclination angles. Computed tomography (CT) should ideally be used to precisely obtain the tooth axis, but even CT requires a reference plane that may not be stable in growing patients. CT also presents an ethical problem. In contrast, the masticatory surface of the molar can easily be measured in the clinic, and the data from the present study can be applied immediately. Lateral inclination of the masticatory surface of the molars can be measured using a ruler, a protractor and a lower plaster model, or cutting an impression at the position of a molar.

Furthermore, careful interpretation of the results should be considered, because the sample size in this study was small. It would be necessary to include more subjects in order to obtain more reliable data. It must also be considered that changes in mandibular intercanine width during natural growth may have occurred, because the age range was wide in the experimental group (6 years 10 months to 11 years 7 months). There are many expansion appliances. In this study, the subjects who wore only a Schwarz plate were selected, to avoid the effects of other appliances.

The increase in intermolar width with the expansion plate was 5.42 mm (maximum: 10.32 mm) and the mean molar inclination change 10.16 degrees during the treatment period (T1–T2). For the retention period (T2–T3), negative values indicating relapse were observed in these measurements, despite using maintenance plates. There were significant changes for the intermolar width (4.12 mm, maximum: 7.67 mm) and molar inclination (8.26 degrees) at all time periods (T1–T3). The molars, therefore, showed a tipping movement during expansion treatment. There was a tendency for the intermolar width and molar inclination to return to the pre-treatment values during the retention period. Seventy-six per cent of the expansion at T2 was maintained at T3 and the change in molar inclination returned to 81 per cent of T2 on average.

No significant correlation between age, treatment period and molar movement was found during the treatment period (Table 4). During the retention period there was significant positive correlation with the amount of expansion and molar inclination, meaning that a longer retention period can maintain a greater amount of expansion. Considering T1–T3, there was a significant correlation between the retention period and the amount of expansion. Extending the retention period is emphasized in order to maintain the expansion effect.

The regression coefficient of the angle of buccal tooth inclination to the intermolar width increment was approximately 0.2 in estimates for T2 and T3 (Table 5). During mandibular expansion, an intermolar width increase of 1 mm would be associated with a buccal inclination of 5 degrees as the sum total of the right and left first molars (unilateral 2.5 degrees).

A case of a narrow dental arch associated with a lingually inclined first molar can be supposed. When the right and left first molars are inclined 10 degrees at each side, the aim is to upright the first molars by 10 degrees each (20 degrees in total for both sides). A limit for mandibular expansion can be supposed as a flat masticatory surface (0 degrees), considering the relapse during the retention period. As far as this assumption is concerned, the permissible limit (PL) for mandibular expansion would thus be estimated by the following equation:

$$PL\ (mm) = 20\ degrees \times 0.2$$

The permissible limit in the above case could be estimated as 4 mm.

Germane *et al.* (1991) and Hnat *et al.* (2000) reported that Ricketts *et al.* (1982) stated that 1 mm of intermolar expansion increased the perimeter by 0.25 mm, although the method for obtaining this guideline was not revealed. According to 3D simulation (Motoyoshi *et al.*, 2002), a 1 mm increase in arch width results in a 0.37 mm increase in the arch perimeter. When these rules are applied, a 1–1.5 mm increase in the arch perimeter is expected.

Conclusion

In order to estimate the permissible limit for mandibular expansion, molar movement was quantitatively investigated. The change in intermolar width was 5.42 mm and the angle of buccal tooth inclination was 10.16 degrees. No significant correlations between age prior to treatment and the treatment period were found compared with the increment of intermolar width and inclination angle. The expansion amount and the retention duration revealed a significant positive correlation. This suggests that the retention period is the most important factor for maintaining the expansion effect.

The regression coefficient of the angle of buccal tooth inclination to the intermolar width increment during mandibular expansion using an expansion plate was calculated. The PL for mandibular expansion can be inferred using the simple equation:

$$PL = (\theta_R + \theta_L) \times 0.2$$

where θ_R and θ_L are the angles of the masticatory surface of the right and left first molar to the occlusal reference plane (Figure 4). This equation would be useful in orthodontic clinics for approximate estimates.

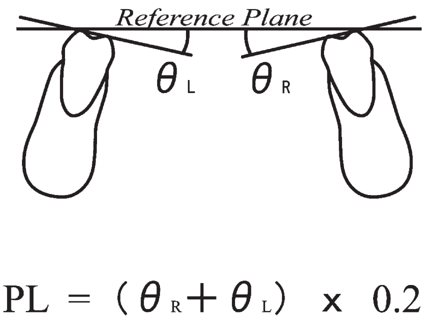

Figure 4 The permissible limit for mandibular expansion. Measuring the angles of the masticatory planes for the right (θ_R) and left (θ_L) first molars to the reference plane, the permissible limit can be estimated from the equation. When the angle, the sum of θ_R and θ_L, was 20 degrees, the permissible limit was estimated as 4 mm from the regression coefficient.

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